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(54) **Apparatus for tension control of a flexible material during winding or unwinding from a drum or reel.**

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Description

FIELD OF THE INVENTION

The present invention relates to apparatus for controlling the tension in a flexible material as it is wound onto or unwound from a drum or reel irrespective of the speed or the weight and size of the drum within the design limitations of the system.

BACKGROUND OF THE INVENTION

The need for a system of the above type is borne out by the fact that certain material, namely glass fibres, plastic fibres, fine metallic wires and filaments, are normally manufactured and wound onto drums or spools for handling and storing. Moreover once these materials are required to be processed and made into a cable or strand, they have to be payed-off from the stored spools into the process which will transform them into another product.

It is during this unwinding (and also the previous winding) process that care must be taken not to stress the material mechanically as this will either impair the future optical, electrical or mechanical properties of the fibre or, at worst, will break the fibre completely.

It is in this area that an accurate system is required which would perform this duty and thus for example render the fibre being paid-off at constant tension producing a constant characteristic pay-off and enabling the required parameters of the final product to be within specified limits.

As a practical example, consider an optical fibre, which is a glass material of certain refractive index and of the order of 100-200 microns in diameter and which, after manufacture, is to be put into cable form. The eventual cable may contain 5, 10 or 20 of these fibres, each payed-off into an extruder. The extruder then extrudes the material and forms a cable which may be used for data transmission or communications.

For paying-off each individual fibre, a tension control system is required that maintains tension at a few grams, ie 15 or 20 g, continuously throughout the pay-off process irrespective of acceleration or speed and independently of the weight or size of the spool. The fibre is very fragile, therefore it is very important that the system can maintain this tension without any deviation.

Previous systems in existence include tension control pay-off's employing DC motors such as described in UK GB-A- 1194771.

This prior system was designed essentially for paying-off metallic wire and had tension control requirements in the range 1 to 5 kg. Thus deviation from the range was not critical since the material being payed-off was not fragile or ductile.

Current needs however require a more precise and accurate method of tension control because of the different and varying characteristics of the material to be handled namely that of fragility as mentioned above.

The prior system discussed above is not capable of providing these needs due primarily to the use of a D.C. motor.

Amongst other disadvantages of employing D.C. machines where sensitivity of operation is essential, is the inclination to cog at low speeds. Moreover hot spots are created in the brushes and commutators and "lurched starting" occurs from stop. The brushes themselves carbonize at zero or low speed, creating high resistance hot spots and ensuing discontinuity rendering the system unusable.

A system for controlling the speed of a polyphase induction motor thereby to control the reeling off of lengths of material at constant tension, is disclosed in US 2571454. This system includes an electron tube connected between two of the motor phase windings which when conducting reduces the speed of the motor, and a transformer for controlling a control electrode of the tube whereby to relate conduction of the tube to a function of the variation of length of the material being held under tension.

In this way control of the motor speed is used to hold the tension of the material constant. However this system lacks refinement and control.

SUMMARY OF THE INVENTION

It is an object of the invention to obviate the disadvantages of the prior art and to provide a tension control system for travelling flexible material of wider application particularly in controlling the tension of material of a filamentary from with a high degree of sensitivity and accuracy.

According to the invention there is provided apparatus for controlling the tension of flexible materials during winding and unwinding processes comprising an A.C. electric motor in the form of a three phase induction motor, said motor being coupled to a spool or reel onto or from which a flexible material is to be wound or unwound respectively, to drive the spool or reel, detector means for detecting changes in tension of the flexible material from a predetermined value during winding or unwinding and providing output signals representative thereof, and control means operatively responsive to said output signals to control the drive of said A.C. motor thereby to maintain the

tension of the material at said predetermined value, characterised in that said control means includes a pair of thyristor banks selectively operable in response to said output signals and connected respectively to a phase winding of the motor, and phase shift actuating means in the form of a capacitor connected across the phase windings tc the thyristor banks to act as a phase determinant of said windings during selective operation of said thyristor banks thereby to effect forward and reverse drive of said induction motor to attain the required tension in said material, or to vary the torque of the motor in either forward or reverse drive as the case may be, to restore the tension to the required value, the rotor of said motor having a high resistance to effect a torque speed characteristic of decreasing torque with increased speed.

The use of an A.C. induction motor removes the problems of D.C. motor control as enumerated above, and by increasing the inherent rotor resistance, the normal torque speed characteristics may be altered so that torque decreases with increasing speed from start.

Control of the output torque of the induction motor is achieved by the control means including a pair of thyristor banks operating selectively on two phases of the three phase induction motor, one for forward and one for reverse drive, with a phase shift actuating device, preferably a capacitor, between the outputs of the thyristor banks to act as the phase determinant of the two phase windings depending on which thyristor bank is energised for forward and reverse drive.

In response to variation of tension in the travelling material from a predetermined value, the forward drive thyristor bank is selectively energised to provide an output voltage varying the output torque through the phase windings to either increase or decrease forward drive as the case may be.

Due to modification of the rotor resistance as explained earlier to provide particular torque speed characteristics, smooth and stable operational variation of motor torque is achievable on a continuous basis thereby to maintain accurate control over the required tension of the travelling filamentary material.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described by way of example with reference to the accompanying drawings wherein

Figure I is a schematic view of apparatus for controlling the tension of a filamentary material being unwound from a drum for use in a subsequent process; and

Figure 2 is a diagram of a suitable circuit for operating the apparatus of Figure I.

BEST MODES OF CARRYING OUT THE INVENTION

The apparatus shown in Figure I comprises a three phase AC induction motor I coupled via a belt and pulley 2 to an output shaft 3 carrying a drum or spool 4 from which fibre or other flexible material W is being unwound at constant tension.

A sensing device for sensing the tension of the travelling material W comprises a V-groove pulley 5 around which the fibre moves, to which is attached a dancer arm 6 operating on a potentiometer 7.

A balance weight 8 is slidable along the dancer arm 6 in order to provide tension in the travelling fibre or other flexible material, and by sliding the weight 8 backwards or forwards along the dancer arm, this tension may be reduced or increased as necessary.

Another method to produce variable tension would be to spring load the dancer arm 6 by an adjustable spring device (not shown).

Additionally although a potentiometer 7 is described as the means for detecting and outputing a signal indicative of variation in tension from the prescribed value, nevertheless it is possible to use other transducers such as inductors, capacitors or a combination of the same to perform a similar function, as will be appreciated by those skilled in the appropriate art.

With reference to the electronic circuit diagram in Figure 2, the potentiometer 7 outputs an error signal representative of variation in tension in the material W from the prescribed value.

The error signal has proportional and derivative gain terms applied to it in amplifier 8 and is then compared by comparators 9 with two ramp wave forms from dual ramp generator I0 one for forward and one for reverse rotation of the motor I.

The output from either one of the comparators 9 is a variable mark-space ratio dependent upon the amplitude of the error signal from the potentiometer 7.

This is combined at logic gates II and I2 with a pulse from trigger pulse generator I3 which is used to trigger an appropriate thyristor bank I4, I5 for forward and reverse drive of the motor I.

The three phase motor I has one phase I6 connected directly to one side of a mains supply LI, the other two phases I7, I8 being controlled by the thyristor banks I4, I5 respectively connected to the other side L2 of the mains supply.

The third phase required for the three phase induction motor is provided by phase shift capacitor I9 to operate the motor I in forward and reverse

drive depending upon which thyristor bank I4, I5 is energised.

In a situation where the fibre W breaks, the dancer arm 6 falls to its lowest position and this is detected by a comparator I9.

This causes a DC current to flow through the motor I by triggering only the thyristor I5 through logic gate 20 thereby rapidly stopping the motor I.

A few seconds after the dancer arm 6 has dropped, the triggering pulse from the thyristor I5 are cut off by the time circuit 2I. A circuit 22 is provided to detect when the mains voltage falls below a predetermined level which cuts off any trigger impulses to the thyristor banks 14, 15.

Additionally in such an event a triac 23 is triggered to provide an output for operating an alarm or similar device (not shown).

A DC power supply 24 provides a positive and negative voltage feeding the dancer arm potentiometer 7 and control circuit electronics.

As explained earlier the motor I is a modified induction motor where the rotor is designed to have a high resistance. This is necessary to change the torque speed characteristics of the motor so that torque falls with increasing speed. The normal induction motor characteristic is one of increasing torque with speed up to approximately 80% of synchronous speed, then the torque decreases torwards zero. This would imply that a normal induction motor would have to be used above 80% of the synchronous speed to achieve stable operation.

In a normal induction motor which is operating at a high slip frequency the rotor appears primarily as an inductance. This causes the magnetic field created by the rotor current to be out of phase with the field induced by the stator.

This problem is overcome by increasing the inherent rotor resistance so reducing the degree of phase shift in rotor current at high slip frequency.

Claims

1. Apparatus for controlling the tension of flexible materials during winding and unwinding processes comprising an A.C. electric motor (1) in the form of a three phase induction motor, said motor being coupled to a spool or reel (4) onto or from which a flexible material (W) is to be wound or unwound respectively, to drive the spool or reel (4), detector means (7) for detecting changes in tension of the flexible material (W) from a predetermined value during winding or unwinding and providing output signals representative thereof, and control means (14,15) operatively responsive to said output signals to control the drive of said A.C. motor (1) thereby to maintain the tension of the material at said predetermined value, characterised in that said control means includes a pair of thyristor banks (14,15) selectively operable in response to said output signals and connected respectively to a phase winding of the motor, and phase shift actuating means, in the form of a capacitor (19) connected across the phase windings, to the thyristor banks (14,15) to act as a phase determinant of said windings during selective operation of said thyristor banks (14,15) thereby to effect forward and reverse drive of said induction motor to attain the required tension in said material, or to vary the torque of the motor in either forward or reverse drive as the case may be, to restore the tension to the required value, the rotor of said motor having a high resistance to effect a torque speed characteristic of decreasing torque with increased speed.

2. Apparatus as claimed in claim 1 wherein said detector means (7) comprises a potentiometer providing error signals representative of variation in tension from the required value, and means for processing the said error signals to provide a train of pulses to trigger the appropriate one of said thyristor banks in accordance with said error signal.

3. Apparatus as claimed in claim 2 wherein said processing means includes comparator means for comparing said error signals with the respective signals from dual ramp generator (10) thereby to output a variable mark-space ratio wave form dependent upon the amplitude of the respective error signal, and logic gate means (11,12,20) for combining a said wave form with said pulse train from trigger pulse means (13) to trigger the appropriate thyristor bank depending upon the sense of said error signal.

4. Apparatus as claimed in any preceding claim wherein a thyristor in one of said thyristor banks (14,15) is triggerable by cable-break detector means to input a D.C. current to said motor to disable same upon the occurrence of a break in said travelling material.

Revendications

1. Appareil pour contrôler la tension de matériaux souples pendant les procédures d'enroulement et de déroulement comprenant un moteur électrique à courant alternatif (1) du type moteur triphasé à induction, ledit moteur étant accou-

plé à une bobine ou à un rouleau (4) sur lequel ou à partir duquel un matériau souple (W) doit être enroulé ou déroulé respectivement, pour entraîner la bobine ou le rouleau (4), un moyen détecteur (7) pour détecter les modifications de tension dans le matériau souple (W) par rapport à une valeur prédéterminée au cours de l'enroulement ou du déroulement et délivrant des signaux de sortie représentatifs de ces variations, et un moyen de commande (14, 15) fonctionnant en réponse auxdits signaux de sortie pour commander l'entraînement dudit moteur à courant alternatif (1) de façon à maintenir la tension du matériau à ladite valeur prédéterminée, caractérisé en ce que ledit moyen de commande comprend deux banques de thyristors (14, 15) pouvant fonctionner de manière sélective en réponse auxdits signaux de sortie et respectivement reliés à un enroulement de phase du moteur, et un moyen de commande de déphasage sous la forme d'un condensateur (19) connecté aux bornes des enroulements de phase des banques de thyristors (14, 15) pour servir de définition des phases desdites enroulements pendant le fonctionnement sélectif desdites banques de thyristors 14, 15) afin de créer un entraînement en avant et en arrière dudit moteur à induction pour atteindre la tension exigée dans le matériau, ou pour faire varier le couple du moteur soit en entraînement avant, soit en entraînement arrière selon le cas, pour établir la tension à la valeur voulue, le rotor dudit moteur ayant un résistance élevée pour obtenir une caractéristique couple-vitesse telle que le couple diminue quand la vitesse augmente.

2. Appareil selon la revendication 1, dans lequel ledit moyen détecteur (7) comporte un potentiomètre délivrant des signaux d'erreur représentatifs de la variation de tension par rapport à la valeur voulue, et un moyen pour traiter lesdits signaux d'erreur afin d'obtenir un train d'impulsions qui déclenche la banque appropriée parmi lesdites banques de thyristors en fonction dudit signal d'erreur.

3. Appareil selon la revendication 2, dans lequel ledit moyen de traitement comprend un moyen comparateur pour comparer lesdits signaux d'erreurs avec lesdits signaux correspondants délivrés par un générateur à double pente (10) de façon à délivrer ainsi une forme d'onde à rapport marquage-espace variable en fonction de l'amplitude du signal d'erreur correspondant, et un moyen de porte logique (11, 12, 20) pour combiner une dite forme d'onde avec ledit train d'impulsions délivrées par le moyen d'impulsions de déclenchement (13) afin de déclencher la banque de thyristors appropriée en fonction du sens dudit signal d'erreur.

4. Appareil selon l'une quelconque des revendications précédentes, dans lequel un thyristor de l'une desdites banques de thyristors (14, 15) peut être déclenché par un moyen détecteur de rupture de câble pour appliquer un courant continu audit moteur et invalider ce moteur en cas de rupture dans ledit matériau en déplacement.

Ansprüche

1. Apparat zum Steuern der Spannung eines flexiblen Materials beim Auf- oder Abwickeln, mit einem Wechselstrommotor (1) in Form eines Dreiphasen-Induktionsmotors, der antriebsmäßig mit einer Spule, Haspel oder Trommel (4) verbunden ist, auf die bzw. von der das flexible Material (W) aufgewickelt bzw. abgewickelt wird, mit Detektormitteln (7) zur Ermittlung von Abweichungen der Spannung des flexiblen Materials (W) von einem vorgegebenen Wert während des Aufwickelns oder Abwickelns sowie zur Erzeugung von entsprechenden Ausgangssignalen, und mit Steuermitteln (14, 15) die auf die Ausgangssignale ansprechen, um den Betrieb des Motors zu steuern und dadurch die Spannung des Materials auf dem vorgegebenen Wert zu halten, dadurch gekennzeichnet, daß die Steuermittel ein Paar von Thyristorschaltstrecken oder -schaltkreisen (14, 15) aufweisen, die selektiv in Abhängigkeit von den Ausgangssignalen betätigbar und jeweils mit einer Phasenwicklung des Motors verbunden sind, daß Phasenschiebermittel in Form eines Kondensators (C) quer zu den Phasenwicklungen mit den Thyristorschaltkreisen (14, 15) verbunden sind, um als phasenbestimmendes Element der erwähnten Wicklungen während der selektiven Betätigung der Thyristorschaltkreise (14, 15) zu dienen, um dadurch eine Vorwärts- und Rückwärtsdrehung des erwähnten Induktionsmotors zur Erzielung der erforderlichen Spannung des Materials zu bewirken, oder um das Drehmoment des Motors im jeweiligen Vorwärts- oder Rückwärtsbetrieb zu ändern, um die Spannung wieder auf den vorgegebenen Wert zu bringen, und daß der Rotor des Motors einen hohen Widerstand aufweist, um eine Drehmoment-Drehzahl-Charakteristik mit einem mit ansteigender Drehzahl abfallenden Drehmoment zu erhalten.

2. Apparat nach Anspruch 1, dadurch gekennzeichnet, daß die Detektormittel (7) ein Potentiometer zur Erzeugung von Fehlersignalen entsprechend der jeweiligen Abweichung der Spannung vom erforderlichen Wert aufweisen, und daß Mittel zur Verarbeitung der erwähnten Fehlersignale vorgesehen sind, um eine Impulsfolge liefern, und zwar zum Triggern des jeweils passenden der Thyristorschaltkreise entsprechend dem Fehlersignal.

3. Apparat nach Anspruch 2, dadurch gekennzeichnet, daß die erwähnten Prozessormittel Komparatormittel zum Vergleichen der Fehlersignale mit entsprechenden Signalen eines dualen Rampengenerators (10) aufweisen, um hierdurch ein Ausgangssignal mit einem variablen Tastverhältnis zu erzeugen, und zwar abhängig von der Amplitude des jeweiligen Fehlersignals, und daß logische Gatter-Mittel (11, 12, 20) vorgesehen sind, um dieses Ausgangssignal mit der erwähnten Impulsfolge von Trigger-Impulsmitteln (13) zu kombinieren, um den entsprechenden Thyristorschaltkreis in Abhängigkeit von dem Fehlersignal, insbesondere in Abhängigkeit vom Inhalt und Vorzeichen des Fehlersignals steuert.

4. Apparat nach einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, daß ein Thyristor in einem der erwähnten Thyristorstromkreise (14, 15) durch Kabelbruchüberwachungsmittel ansteuerbar ist, um einen Gleichstrom an den erwähnten Motor zu liefern, um diesen beim Auftreten eines Bruches in dem bewegten Material unwirksam zu schalten bzw. stillzusetzen.

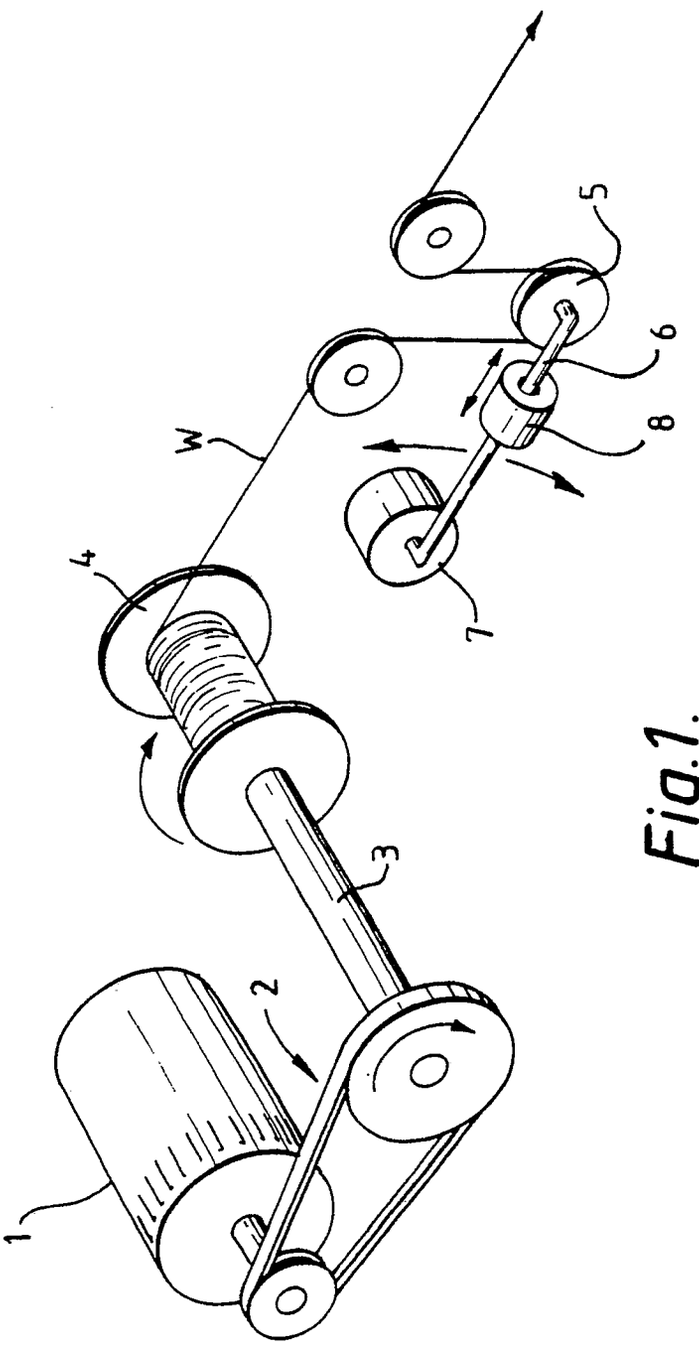

Fig.1.

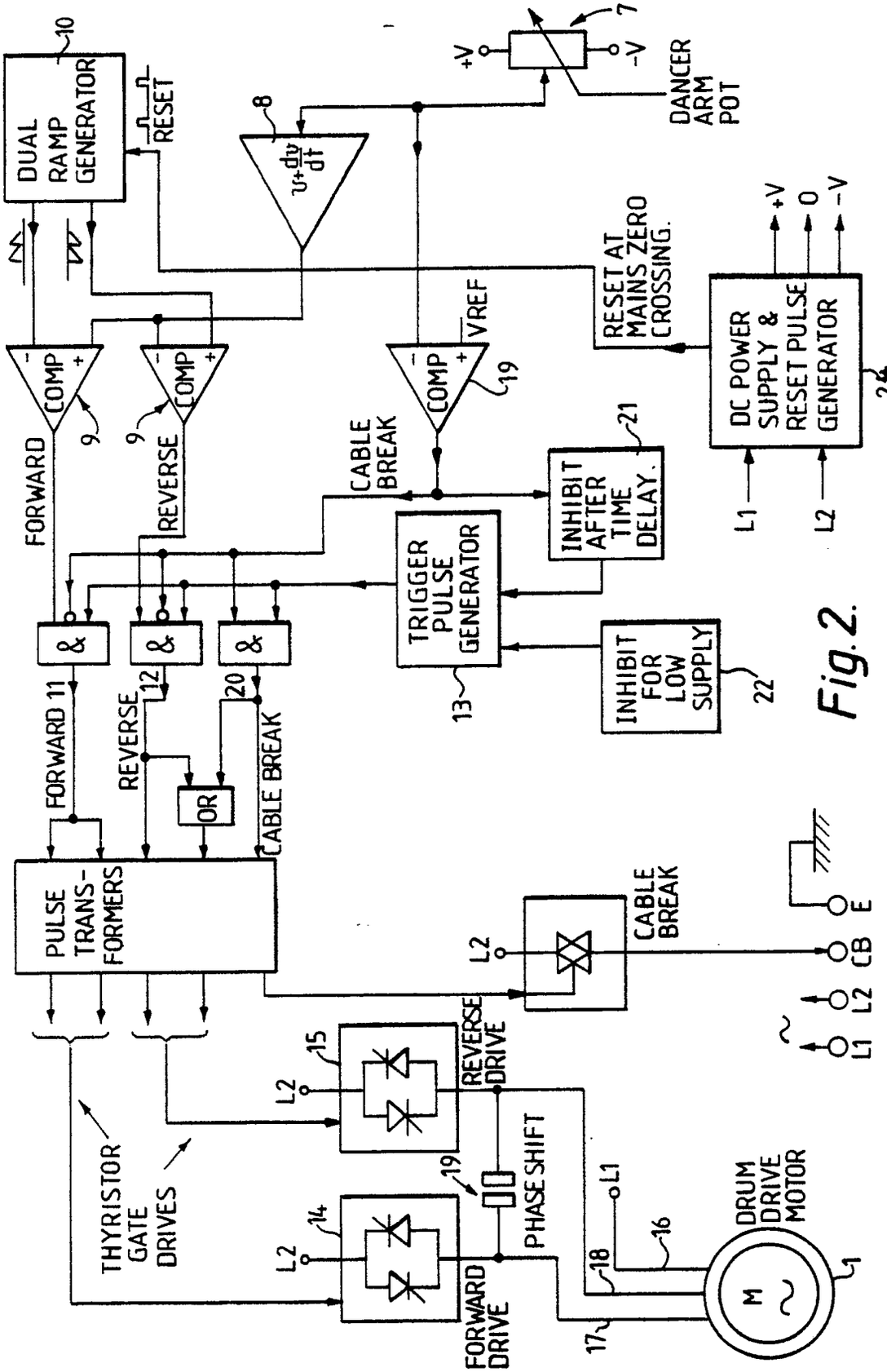
DUAL RAMP GENERATOR
10
RESET
8
+V
-V
7
DANCER ARM POT
RESET AT MAINS ZERO CROSSING.
DC POWER SUPPLY & RESET PULSE GENERATOR
24
+V
0
-V
L1
L2
VREF
COMP
19
FORWARD
REVERSE
9
CABLE BREAK
21
INHIBIT AFTER TIME DELAY.
TRIGGER PULSE GENERATOR
13
INHIBIT FOR LOW SUPPLY
22
&
FORWARD 11
REVERSE 12
20
CABLE BREAK
OR
PULSE TRANS-FORMERS
THYRISTOR GATE DRIVES
L2
CABLE BREAK
CB
E
L1
15
REVERSE DRIVE
14
FORWARD DRIVE
PHASE SHIFT
18
16
17
DRUM DRIVE MOTOR
M

Fig.2.